BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Use of Goldstone Mars Station for Reception of LM Television from Lunar Surface
Case 900

DATE: June 12, 1968

FROM: J. J. Hibbert
J. T. Raleigh
R. L. Selden

ABSTRACT

Reception of television from the lunar surface during the first manned lunar landing of the Apollo Program will provide evidence of America's preeminence in space, demonstration of achievement of a national goal and to some degree enhance the scientific return from the lunar landing. In the event the Lunar Module's (LM) erectable antenna, required for television transmission under worst case conditions, is not available, television as a means of communication may be lost. If, however, the 210 foot diameter, properly equipped antenna facility at Goldstone, California was available, some television reception would be possible. If the reliability normally required of Manned Space Flight Network ground stations were waived, the 210 foot antenna site at Goldstone could be implemented as a backup capability with little technical difficulty. Additions or modifications required at this site include: (a) adjustment of the receiving bandwidth of the preamplifier and receiver, (b) provision for wideband FM (e.g. 4 MHz) demodulation, and (c) interconnecting existing microwave facilities already in existence at Goldstone.

It is recommended that these changes be implemented at the 210 foot Goldstone antenna facility, so that it could provide limited Apollo support

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BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Use of Goldstone Mars Station for Reception of LM Television from Lunar Surface
Case 900

DATE: June 11, 1968

FROM: J. J. Hibbert
J. T. Raleigh
R. L. Selden

MEMORANDUM FOR FILE

The reception of television from the Lunar Module (LM) on the moon's surface during the first lunar landing mission will be first-hand evidence of the successful accomplishment of a major objective of the Apollo Program. It will permit all of us to participate in real-time in a significant extension of the frontier of knowledge. This participation will repay, in a small way, for the expenditure of time and treasure by the people of the United States who sponsored the Apollo Program. This is reason enough for providing the technical support needed to assure such television. This memorandum discusses the very important role that the Mars station at Goldstone could play in providing insurance of television reception from the lunar surface for the initial lunar landing.

The LM will carry a television camera and can transmit television signals in the frequency modulation (FM) mode of its unified S-band (USB) transponder. In the FM mode, the LM can transmit concurrently the astronaut voice and biomedical data, high or low bit rate (51.2 or 1.6 kbps) telemetry and television. Unlike the USB system in the Command and Service Modules (CSM), which can operate in the FM mode and in the Phase Modulation (PM) mode at the same time, the LM can operate in either the PM mode or the FM mode, but not both concurrently. Since the PM mode is required for ranging and doppler tracking, the LM will employ the PM mode on its descent to and its ascent from the lunar surface. This precludes the transmission of television from the LM on its way down to and on its way up from the moon.

On the lunar surface, the LM will use the FM mode for television transmission. The astronauts will erect a high gain antenna ("erectable" antenna) on the lunar surface. This antenna will provide a net increase of effective radiated power of about 8 dB over that provided by the high gain antenna ("steerable" antenna) mounted on the LM. This added gain is needed to be sure that the television, voice and telemetry signals can be received by the deep space MSFN stations for the worst case situation (e.g. lowest specified transmitted power, highest received noise figure, etc.). The calculated performance of the LM communications link from the lunar distance in the FM mode is given in Appendix I and is summarized in Table I. It should be noted that television performance is better than that of the telemetry and voice.

From Table I, it is apparent that it should be possible to receive television, voice and telemetry from the lunar surface at an MSFN 85' station using a steerable antenna on the LM if the transmission link elements exhibit normal performance, but not with worst case performance. With an erectable antenna on the lunar surface, the performance margin is sufficient for an MSFN 85' diameter antenna even in the predicted worst case for the LM FM mode.

If trouble should prevent the raising of the erectable antenna, it would not be possible to obtain television at an MSFN station from the moon in the worst case. On the other hand, it would always be possible to receive television, voice and telemetry at the Mars station from a LM on the lunar surface using only the steerable antenna.

The Mars station could support the Apollo lunar landing mission with a nominal investment. Specifically, the following additions would be required:

(1) Adjust the receiving bandwidth of the Mars preamplifier and receiver to permit it to receive the LM FM frequency 2280-2285 MHz as has been done for the DSN station at the Pioneer site which is used to back up the Apollo MSFN site at Goldstone. The present Mars receiver operates in the 2290-2300 MHz band (as did the Pioneer DSN site) but can be adjusted to cover the lower frequency band at a slight penalty in noise figure (less than 1 dB). The antenna feed and maser preamplifier are the same as used in Pioneer.

(2) Provide FM demodulators at the Goldstone Mars site to recover the LM video, voice and telemetry for transmission over existing video links to the Pioneer site via the Echo site communication center.

(3) Interconnect the video links from the Echo site communication center to the Pioneer site with the video links from Pioneer Wing site to the Apollo MSFN site; this is the

link that is normally used in Apollo to transmit video from the Pioneer wing site to the MSFN station (see Appendix II).

None of these additions are expensive so that a Mars backup of the Apollo Mission could be obtained at a nominal cost.

Other ramifications of the Mars backup support of initial lunar landing missions are:

(1) The moon must be in the field of view of the Mars station at Goldstone. This occurs for a period of 8 to 12 or 13 hours a day depending upon the time of month.

(2) The operational time line used by the astronauts must permit their usage of the television camera during the time the moon is in line of sight of Goldstone.

(3) On the initial mission, the USB transponder could be switched to the FM mode shortly after landing and before the deployment of the erectable antenna to determine whether or not the 85' MSFN station was receiving sufficient signal using only the LM steerable antenna. If sufficient signal was available, there would be no need to deploy the erectable antenna. With the 210' antenna as a backup, there would be assurance that subsequent changes in link characteristics would not prevent acceptable communications.

(4) With the support outlined in (3), it would be possible to transmit a television picture of the first American's first step onto the moon's surface. This would require the use of the LM steerable antenna and a change from the present plans of carrying the television camera (which weighs about 15 pounds) in the descent stage to one having it stowed in the ascent stage. The camera would then be available for use immediately after the lunar landing. In the writers opinion, the televising of this event merits strong support measures excluding, of course, any significant impact on crew safety.

SUMMARY

It is apparent that the use of the 210' antenna site at Goldstone would provide a marked advantage in communication effectiveness in supporting the initial Apollo lunar landing mission at a very nominal cost.

J. J. Hibbert

J. T. Raleigh

R. L. Selden

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Attachments
Table I
Appendices I&II

TABLE I

PERFORMANCE MARGINS FOR LM COMMUNICATIONS

(FM Mode - High Power)

	85' MSFN Station		210' Mars Station	
	Nominal	Worst Case	Nominal	Worst Case
Erectable Antenna				
51.2 kbps Telemetry	+6.1 dB	+0.2 dB	+14.1 dB	+8.2 dB
Voice-Biomedical Data	+7.1	+1.4	+15.1	+9.4
Television	+10.8	+6.6	+18.8	+14.6
1.6 kbps Telemetry	+12.8	+7.2	+20.8	+15.2
Voice-Biomedical Data	+7.1	+1.4	+15.1	+9.4
Television	+10.8	+6.6	+18.8	+14.6
Steerable Antenna				
51.2 kbps Telemetry	-2.1	-8.3	+5.9	-0.3
Voice-Biomedical Data	-1.1	-7.1	+6.9	+0.9
Television	+2.6	-1.9	+10.6	+6.1
1.6 kbps Telemetry	+4.6	-1.3	+12.6	+6.7
Voice-Biomedical Data	-1.1	-7.1	+6.9	+6.9
Television	+2.6	-1.9	+10.6	+6.1

APPENDIX I

COMPUTED PERFORMANCE OF LM TO MSFN COMMUNICATIONS PERFORMANCE USING THE FREQUENCY MODULATION MODES (TV)

This appendix presents the data used to determine the computed circuit margins given in Table I. All data was obtained from the NASA-MSC/ISD Master Parameter List, dated March 12, 1968. The channel requirements, that is the input signal to noise ratio required for proper operation of the telemetry, television and voice and biomedical telemetry services are taken from "A Performance Analysis of the Apollo Unified S-Band Communications System For a Typical Lunar Mission, by G. D. Arndt, C. T. Dawson and R. W. Moorehead. (MSC Internal Note MSC-EB-R-67-1, May 1, 1967). It should be pointed out that the communications system to be used by the astronauts on the lunar surface (extra-vehicular communication system)is being redesigned. It is anticipated that this redesign will raise the channel requirements for the voice and bio-medical telemetry channel by a few db.

1. Received Signal Power (LM Transmitting with High Power)

LM Antenna Configuration	85' MSFN Station		210' Station	
	Nom	Worst Case	Nom	Worst Case
Erectable Antenna	-122.3dBW	-125.9dBW	-114.3dBW	-117.9dBW
Steerable Antenna	-130.5dBW	-134.9dBW	-122.5dBW	-126.4dBW

2. Ground Station Receiver Noise

Noise Temperature (Both 85' and 210' Station)	210°K
FM Demodulator Bandwidth (worst case)	4.8 MHz
Total Ground Station Receiver Noise Power	-138.6dBW

3. Input Signal to Noise Ratios

LM Antenna Configuration	85' MSFN Station		210' Station	
	Nom	Worst Case	Nom	Worst Case
Erectable	16.3dB	12.7dB	24.3dB	20.7dB
Steerable	8.1dB	4.2dB	16.1dB	12.2dB

4. Channel Performance Requirements

	Nom	Worst Case
High Bit Rate Telemetry (51.2Kbps) 10^{-6}BER	10.2dB	12.5dB
Low Bit Rate Telemetry(1.6Kbps) 10^{-6}BER	3.5dB	5.5dB
Voice and Bio-Medical Telemetry	9.2dB	11.3dB
Television	5.5dB	6.1dB

5. Performance Margins

LM Configuration	85'Station		210' Station	
	Nom	Worst Case	Nom	Worst Case
Erectable-Hi Power				
51.2 TLM	+6.1	+0.2	+14.1	+8.2
Voice-Bio	7.1	1.4	15.1	9.4
Television	10.8	6.6	18.8	14.6
1.6 TLM	12.8	7.2	20.8	15.2
Voice-Bio	7.1	1.4	15.1	9.4
Television	10.8	6.6	18.8	14.6
Steerable-Hi Power				
51.2 TLM	-2.1	-8.3	5.9	-0.3
Voice-Bio	-1.1	-7.1	6.9	0.9
Television	2.6	-1.9	10.6	6.1
1.6 TLM	4.6	-1.3	12.6	6.7
Voice-Bio	-1.1	-7.1	6.9	0.9
Television	2.6	-1.9	10.6	6.1

APPENDIX II

USB FACILITIES AT GOLDSTONE

In the tracking station complex of Goldstone, California, the Jet Propulsion Laboratory (JPL) and Goddard Space Flight Center (GSFC) have a number of antenna facilities. These include the prime MSFN 85 foot antenna site and a Wing Site at the JPL 85 foot Pioneer Site. The JPL 210 foot antenna, referred to as the Mars site, has been discussed as a potential Apollo receiving site. This memorandum discusses our understanding of the facilities and the technical problems which exist in the implementation of this site for limited Apollo support.

In summary, the radio frequency receiving equipment at the 210 foot site is similar to that which has already been modified for MSFN Apollo support. A microwave network exists that interconnects the JPL antenna sites; the MSFN wing at the Pioneer Site is connected to the Prime MSFN site by a special microwave facility. Therefore, to provide limited Apollo support from a technical standpoint, it is necessary to apply some of the already proven modifications and provide a limited amount of equipment, such as a Signal Data Demodulator, to assure compatibility of the existing radio receiver equipment and microwave relay networks.

Discussion

The principle MSFN support by 85 foot antennas is provided by an X-Y mounted antenna and the MSFN equipment at the GSFC site. A wing has been added to the previously existing JPL Deep Space Station (DSS) site which is called Pioneer (DSS/11) for MSFN support. Plans may require the use of both for normal lunar mission activity, but either site should be able to support both the CSM and LM spacecraft. As a result, the normal configuration of each station can support up to four PM links and two FM links and the complex can support 0 to 8 PM and 0 to 4 FM links. One site can be considered from a receiver standpoint as the same as any other dual MSFN site.

The Wing site is connected to the Prime site by a two-way microwave relay system built for GSFC by Collins Radio Corp. A description of the microwave system is included in "Functional Description of the Apollo Unified S-Band Data Transmission Links," X-506-66-36, John J. Schwartz, February 1, 1966.

The phase modulated (PM) signals received from the Apollo Spacecraft are demodulated in the MSFN receiver located at the Wing site and the down-link voice and/or subcarriers are relayed over the microwave link in a video channel from the Wing to the Signal Data Demodulator System (SDDS) at the prime MSFN site. The frequency modulated (FM) signals are extracted from the MSFN receiver at a 50 mHz intermediate frequency (IF). At the Wing site, this 50 mHz IF is converted to a standard microwave relay IF of 70 mHz with a translator that is included in the relay equipment. At the prime site, the 50 mHz is recovered and delivered to the SDDS FM demodulator which is a wide band modulation tracking phase-locked loop.

The 210 ft. antenna is a unique installation. The planning, design, construction, and testing of the antenna presented many challenging problems, which have been resolved in a sound engineering fashion. From a radio system standpoint, this installation has used the technology which had been developed from other DSIF work. In particular, the antenna feed assembly, traveling wave maser, and S-band receiver are the same as those used at other DSN sites. Each of these items have been discussed in more detail in the JPL Space Program Summaries. The Deep Space Network facilities and activities have been reported on in the series 37-XX, Volume III (recently changed to Volume II).

The important thing to note is that the antenna feed cone and traveling wave maser are the same on the 210 ft. antenna[1] and the 85 ft. Pioneer antenna, which is being used as the MSFN backup site.

The Space Program Summaries do report that work is in progress on a second generation traveling wave maser, however, the existing model has been tuned to support the MSFN system located at the Pioneer Site.[2] It is our understanding

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[1] Cassegrain Feed System for the Advanced Antenna System SPS No. 37-32, Volume III, March 31, 1965, pp. 74-80.

Orientation of DSIF Cassesrain Cones SPS No. 37-37, Volume II, September 30, 1967, pp. 98-104.

[2] DSN (MSFN Apollo Wings) Backup System SPS, Volume 37-48, Volume II, November 30, 1967, pp. 157-169.

that the gain of the maser is reduced for MSFN support in order to maintain the fixed gain bandwidth product of the maser. As a result, the noise temperature of the system is increased since the switching and equipment following the maser provides a larger contribution to the overall system performance (because of the lower front end gain). It is concluded that although other improvements have and will be made to the 210 ft. antenna feed and maser systems, the experience to support the Apollo signals exists and can be technically implemented quite easily.

The radio frequency receiver at the 210 ft. antenna site is similar to those at all the other DSIF sites. There are basically three configurations of S-band receivers. The original was known as the Goldstone duplicate standard (GSDS) S-band RF System[3]. This system was modified for MSFN support and was supplied to GSFC for integration into the MSFN stations. Somewhat analogous to the Block I and Block II CSM, the DSN configuration has become known as the Block I S-band system and the MSFN has become known at JPL as the Block II system. The major differences between Block I and Block II are the carrier frequencies that can be received and the carrier tracking loop bandwidths.

ODTA and JPL have developed a Block III C concept which, with the interchange of some modules, allows MSFN-DSN cross-program support. (This modification is accompanied in the MSFN with a change to the Mark I Ranging System known as Block IIB Mods).

The present implementation of the Pioneer site includes two wings on the support building at the 85 ft. antenna. One wing has an MSFN receiver, the other wing has the DSN receiver. The data on the incorporation of the IIIC modifications is not readily available, but it is known that several MSFN stations which supported the last Apollo mission have been modified. In summary, the DSN receiver modifications required to support Apollo are developed and a wealth of experience exists on the implementation of these modifications which allow the cross-program support. It is doubtful that the exact hardware would be required since knowledgeable engineers have provided such monitoring on DSN supported spacecraft (e.g. Lunar Orbiter) at the Block II MSFN sites.

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[3]GSDS 1964, S-Band RF System, SPS, Volume 37-28, Volume III, July 31, 1964, pp. 33-39.

BELLCOMM, INC.

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